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(54) Title: CATALYTIC EQUILIBRATION OF SELECTED HALOCARBONS		
(57) Abstract <p>A method is disclosed for increasing in a composition the mole fraction of a compound selected from the group CF_3CHCl_2, CF_3CHF_2 and CF_3CHClF relative to the total mole fraction of the other two compounds of the group. The method comprises (a) providing a gaseous composition comprising at least one compound of said group provided that (i) if the selected compound is either CF_3CHCl_2 or CF_3CHF_2, said gaseous composition comprises CF_3CHFCl and the mole fraction of the selected compound relative to the other two compounds in said gaseous composition is less than its equilibrium amount at 50 °C, and (ii) if the selected compound is CF_3CHFCl, said gaseous composition comprises both CF_3CHCl_2 and CF_3CHF_2 and the mole fraction of the selected compound relative to the other two compounds in said gaseous composition is less than its equilibrium amount at 500 °C; (b) contacting said gaseous composition with a catalyst selected from the group of catalysts consisting of catalysts comprising chromium as an oxide, as a halide or as a halided oxide, in a valence state of three to six, and supported catalysts containing at least one metal selected from cobalt, copper, iron, manganese, nickel and zinc for a time sufficient to provide substantial equilibrium between the three compounds having said formula; and (c) providing during said catalyst contact a temperature within the range of about 50 °C to 500 °C at which the mole fraction of the selected compound relative to the other two compounds increases.</p>		

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TITLE

CATALYTIC EQUILIBRATION OF SELECTED HALOCARBONS

5

FIELD OF THE INVENTION

This invention relates to the preparation of halogen substituted hydrocarbons and more particularly to the use of equilibrium reactions for preparing
10 halogen substituted hydrocarbons containing fluorine.

BACKGROUND OF THE INVENTION

There has been considerable recent interest in halogen substituted ethanes containing fluorine and hydrogen. Many of these materials can be used not only
15 as blowing agents and refrigerants, but also as starting materials for preparing other useful compounds.

U.S. Patent No. 4,766,260 discloses an improved gas-phase process for the manufacture of 1,1,1-trifluorodichloroethane (i.e., HCFC-123) and
20 1,1,1,2-tetrafluorochloroethane (i.e., HCFC-124) by contacting a suitable tetrahaloethylene with hydrogen fluoride in the presence of a selected metal on a high fluorine content alumina support, the reaction being conducted under controlled conditions whereby the
25 production of pentafluoroethane (i.e., HFC-125) is minimized. U.S. Patent No. 4,766,260 discloses that intermediates formed during the course of the invention, such as $\text{CHF}_2\text{CClF}_2$, CHClFCClF_2 , $\text{CHCl}_2\text{CClF}_2$, CClF=CCl_2 and $\text{CHCl}_2\text{CCl}_2\text{F}$ can be recycled to the reactor for the
30 production of additional 1,1,1-trifluorodichloroethane and 1,1,1,2-tetrafluorochloroethane; and that 1,1,1-trifluorodichloroethane can be recycled to the reactor for the production of additional 1,1,1,2-tetrafluorochloroethane when this is desired.
35 It is often desirable to avoid the use and production of

unsaturated materials, and there is thus a need for additional techniques which selectively yield saturated halogen substituted hydrocarbons containing fluorine and hydrogen such as HCFC-123, HCFC-124 and HFC-125.

5 Chromium-containing catalysts have been used in conjunction with disproportionations and other reactions involving halogen-substituted ethanes. For example, U.S. Patent No. 4,145,368 discloses a process for manufacturing 1,1,1-trifluoro-2,2-dichloroethane by
10 reaction of 1,1,1-trifluoro-2,2,2-trichloroethane with 1,1,1-trifluoro-2-chloroethane over a solid catalyst such as Cr_2O_3 . The use of catalysts containing chromium in a valence state of three to six and either oxide alone or oxide and fluoride is disclosed. U.S. Patent
15 No. 3,787,331 discloses use of a chromium-containing catalyst in disproportionating and isomerizing $\text{CF}_2\text{Cl}-\text{CFCl}_2$; and U.S. Patent No. 3,651,156 exemplifies the disproportionation reaction of $\text{C}_2\text{F}_3\text{Cl}_3$ passed over a catalyst obtained by fluorination of chromium hydroxide.
20 U.S. Patent 4,605,798 discloses a process for the preparation of trichlorotrifluoroethanes, dichlorotetrafluoroethanes, and monochloropentafluoroethane utilizing three reactors, one of which is used for a fluorination-dismutation reaction. The catalysts used in these
25 reactors comprise supported or non-supported oxides or halides of chromium among others.

SUMMARY OF THE INVENTION

We have found that catalysts selected from the group of catalysts consisting of catalysts containing
30 chromium in a valence state of three to six as an oxide, a halide, or as halided oxide and supported catalysts containing at least one metal selected from cobalt, copper, iron, manganese, nickel and zinc are effective in equilibrating CF_3CFHCl with its disproportionation
35 products CF_3CHCl_2 and $\text{CF}_3\text{CF}_2\text{H}$; and that the equilibration

constant for the disproportionation varies with temperature over the range of 50°C to 500°C, with the formation of CF_3CHFCl becoming more favored as the temperature increases.

5 The present invention involves at least partial equilibration of the halohydrocarbon CF_3CHFCl (HCFC-124) with halohydrocarbons CF_3CHCl_2 (HCFC-123) and $\text{CF}_3\text{CF}_2\text{H}$ (HFC-125) using a vapor phase reaction. In this equilibration the halogens on the carbon containing the
10 hydrogen exchange. All the compounds involved in the interconversion contain exactly two carbons and one hydrogen.

 A method is provided in accordance with this invention for increasing in a composition the mole
15 fraction of a selected compound of the formula $\text{CF}_3\text{CHF}_x\text{Cl}_{2-x}$ where x is an integer from 0 to 2 relative to the total mole fraction of the other two compounds having said formula which comprises the steps of: (a) providing a gaseous composition comprising at least one
20 compound of said formula provided that (i) if the selected compound is either CF_3CHCl_2 or CF_3CHF_2 , said gaseous composition comprises CF_3CHFCl and the mole fraction of the selected compound relative to the other two compounds in said gaseous composition is less than
25 its equilibrium amount at 50°C, and (ii) if the selected compound is CF_3CHFCl , said gaseous composition comprises CF_3CHCl_2 and CF_3CHF_2 and the mole fraction of the selected compound relative to the other two compounds in said gaseous composition is less than its equilibrium
30 amount at 500°C; (b) contacting said gaseous composition with a catalyst selected from the group of catalysts consisting of catalysts comprising chromium as an oxide, as a halide or as a halided oxide, in a valence state of three to six, and supported catalysts containing at
35 least one metal selected from cobalt, copper, iron,

manganese, nickel and zinc, for a time sufficient to provide substantial interconversion among the three compounds having said formula; and (c) providing during said catalyst contact a temperature within the range of about 50°C to 500°C at which the mole fraction of the selected compound relative to the other two compounds increases.

The method, preferably supplemented by the steps of separating at least a portion of the selected compound from the interconverted composition of step (c); and contacting at least a portion of the compounds remaining after said separation with a catalyst selected from said group of catalysts at a temperature within the range of about 50°C to 500°C and for a time sufficient to produce an additional quantity of said selected compound by providing substantial interconversion; can be advantageously included in a process for preparing halogen substituted ethanes to increase the yield of the selected compound relative to the total yield of the other two compounds having the above-referenced formula.

DETAILS OF THE INVENTION

The invention deals with processes employing the interconversion of CF_3CFHCl (HCFC-124) with CF_3CHCl_2 (HCFC-123) and $\text{CF}_3\text{CF}_2\text{H}$ (HFC-125) using selected catalysts. The preferred catalysts of this invention comprise chromium in a valence state of three to six as an oxide (e.g., Cr_2O_3), as a halide (e.g., CrX_3 where each X is selected from chlorine and fluorine) or as a halided oxide (e.g., Cr_2O_3 treated with CCl_3F or CCl_4). The chromium catalysts of this invention can be supported or unsupported. Other catalysts which may be used for the interconversion of this invention include supported catalysts containing at least one metal selected from cobalt, copper, iron, manganese, nickel and zinc.

A method is provided in accordance with this invention for increasing in a composition the mole fraction of a selected compound of the formula $\text{CF}_3\text{CHF}_x\text{Cl}_{2-x}$ where x is an integer from 0 to 2 relative to the total mole fraction of the other two compounds having said formula comprising the steps of: (a) providing a gaseous composition comprising at least one compound of said formula provided that (i) if the selected compound is either CF_3CHCl_2 or CF_3CHF_2 , said gaseous composition comprises CF_3CHFCl and the mole fraction of the selected compound relative to the other two compounds in said gaseous composition is less than its equilibrium amount at 50°C , and (ii) if the selected compound is CF_3CHFCl , said gaseous composition comprises both CF_3CHCl_2 and CF_3CHF_2 and the mole fraction of the selected compound relative to the other two compounds in said gaseous composition is less than its equilibrium amount at 500°C ; (b) contacting said gaseous composition, with a catalyst selected from the group of catalysts consisting of catalysts comprising chromium as an oxide, as a halide or as a halided oxide, in a valence state of three to six, and supported catalysts containing at least one metal selected from cobalt, copper, iron, manganese, nickel and zinc, for a time sufficient to provide substantial interconversion among the three compounds having said formula; and (c) providing during said catalyst contact a temperature within the range of about 50°C to 500°C at which the mole fraction of the selected compound relative to the other two compounds increases.

Suitable compositions comprising the compounds of the formula $\text{CF}_3\text{CHF}_x\text{Cl}_{2-x}$ may be provided as a product (e.g., a reaction product) containing all three compounds. Alternatively either HCFC-124, or both HCFC-123 and HFC-125 may be provided. It will be

evident that even where HCFC-124 is initially provided without HCFC-123 and/or HFC-125 or where both HCFC-123 and HFC-125 are initially provided without HCFC-124, even partial equilibration will produce a quantity of the compound(s) not initially provided. Accordingly, gaseous mixtures comprising all three compounds of the formula $\text{CF}_3\text{CHF}_x\text{Cl}_{2-x}$ may be provided in accordance with step (a), and interconversion (i.e., disproportionation or conproportionation) among HCFC-124, HCFC-123, and HFC-125 may be achieved in accordance with this invention at suitable temperatures.

The chromium catalysts of this invention can be used as a single component or combined with a support such as alumina or carbon. The catalysts of this invention which do not contain chromium (i.e., catalysts containing cobalt, copper, iron, manganese, nickel and/or zinc) should be supported. Supported catalysts (e.g., supported chromium oxides) can be prepared by impregnation of a pre-formed support, co-precipitation or co-evaporation. Such methods are well-known in the art. Reference is made to U.S. Patent No. 4,766,260 for further discussion of supported metal catalysts.

The preferred catalysts of this invention contain chromium as an oxide, as a halide, or as a halided oxide. By halided chromium oxide is meant a material comprising chromium, oxygen, and a halogen, the halogen being either chlorine or fluorine. The halogen content can vary from 1% to nearly 10% with either halogen. The remainder of the material may include chromium oxide.

Catalysts based on fluorided chromia (Cr_2O_3) can be prepared prior to reaction by treatment with a vaporizable fluorine-containing fluorinating compound, such as HF , CCl_3F (CFC-11), CClF_2 (CFC-12), or $\text{CCl}_2\text{FCClF}_2$ (CFC-113). Catalysts based on chlorided chromia can be prepared prior to reaction by treatment with a

vaporizable chlorine-containing chlorinating compound, such as CCl_4 or C_2Cl_4 . The surface halogenation takes place at elevated temperatures until the desired degree of fluorination is obtained, e.g., at about 200°C to about 450°C . The treatment can conveniently be done in the reactor which is to be used for equilibration.

A suitable catalyst may be prepared, for example, as follows:

A quantity of chromia (Cr_2O_3) is dried until essentially all moisture is removed, e.g., for about 2 hours at 400°C . The dried catalyst is then transferred to the reactor to be used. The temperature is then lowered to about 200°C , and CFC-12 in N_2 is passed through the reactor. The N_2 can be gradually reduced until only CFC-12 is being passed through the reactor. At this point the temperature is increased to about 350°C and held at that temperature to convert the Cr_2O_3 to the desired halide content. If too much activator is used, the resulting bulk CrX_3 will not be as active as surface treated oxide. If too little is used, further activation will occur when the actual process is started.

The interconversion using the catalyst of the instant invention is conducted at 50°C to 500°C , preferably about 200°C to 400°C . Depending upon the selected compound desired, mixtures of HCFC-124, HCFC-123 and HFC-125 in any proportion may be used as feed to the equilibration reactor. Preferably, where it is desirable to produce CF_3CFHCl , the gaseous composition of step (a) is derived from a feed of CF_3CHCl_2 and CF_3CHF_2 ; and where it is desirable to produce CF_3CHCl_2 and/or CF_3CHF_2 , the gaseous composition of step (a) is derived from a feed of CF_3CFHCl .

The contact time in the vapor phase process can vary widely depending on the degree of conversion

desired and generally will be about 5 to 180 seconds, preferably about 60 to 90 seconds.

The halohydrocarbon may be fed as is or diluted with an inert gas such as nitrogen, helium or argon.

5 The interconversion of HCFC-124 with HCFC-123 and HFC-125 may be conducted in any suitable reactor, including fixed and fluidized bed reactors. The reaction vessel should be constructed from materials which are resistant to the corrosive effects of hydrogen
10 halides, such as Hastelloy® nickel alloy and Inconel® nickel alloy.

 In accordance with this invention a method is provided for increasing the yield of a selected compound of the formula $\text{CF}_3\text{CHF}_x\text{Cl}_{2-x}$ where x is an integer from 0
15 to 2 relative to the total yield of the other two compounds having said formula in a process for preparing halogen substituted ethanes containing fluorine. A preferred method includes the steps of (a) providing a gaseous composition comprising at least one compound of
20 said formula provided that (i) if the selected compound is either CF_3CHCl_2 or CF_3CHF_2 , said gaseous composition comprises CF_3CHFCl and the mole fraction of the selected compound relative to the other two compounds in said gaseous composition is less than its equilibrium amount
25 at 50°C , and (ii) if the selected compound is CF_3CHFCl , said gaseous composition comprises both CF_3CHF_2 and CF_3CHCl_2 and the mole fraction of the selected compound relative to the other two compounds in said gaseous composition is less than its equilibrium amount at
30 500°C ; (b) contacting said gaseous composition with a catalyst selected from the group of catalysts consisting of catalysts comprising chromium as an oxide, as a halide or as a halided oxide, in a valence state of three to six, and supported catalysts containing at
35 least one metal selected from cobalt, copper, iron,

manganese, nickel and zinc, for a time sufficient to provide substantial interconversion among the three compounds having said formula; and (c) providing during said catalyst contact a temperature within the range of about 50°C to 500°C at which the mole fraction of the selected compound relative to the other two compounds increases; (d) separating at least a portion of the selected compound from the interconverted composition of step (c); and (e) contacting at least a portion of the compounds remaining after said separation with a catalyst selected from the group of catalysts consisting of catalysts comprising chromium as an oxide, as a halide or as a halided oxide in a valence state of three to six, and supported catalysts containing at least one metal selected from cobalt, iron, manganese, nickel, and zinc, at a temperature within the range of about 50°C to 500°C and for a time sufficient to produce an additional quantity of said selected compound by providing substantial interconversion.

Pressure is not critical. Atmospheric and superatmospheric pressures are the most convenient and are therefore preferred.

Separation of the selected compound as provided by step (d) may be accomplished by conventional methods (e.g., fractional distillation). The catalyst contact step (e) can be accomplished in a separate contact unit or can, where suitable, be accomplished by recycling of compounds remaining after separation to the catalyst contact of steps (b) and (c).

HFC-125 and HCFC-123 may be used in accordance with this invention to provide HCFC-124 which is an important reagent for producing the refrigerant $\text{CF}_3\text{CH}_2\text{F}$. This invention allows HFC-125 produced during commercial HCFC-124 production by hydrofluorination to be recycled with intermediate HCFC-123 for added HCFC-124

production. The interconversion can also produce HFC-125 from HCFC-124 without requiring equipment resistant to HF. The product fluorocarbons of this invention are useful as refrigerants.

5 Practice of the invention will be made further apparent from the following non-limiting examples.

EXAMPLES

In illustrative Examples 1 through 6 which follow, all parts and percentages are by weight and all
10 temperatures are Celsius. All product compositions are relative area based on gas chromatographic analyses, and are uncorrected for relative response.

General Procedure for Equilibration in Examples 1 through 6

15 The temperature was adjusted to the indicated values, followed by the initiation of flow of the halohydrocarbon(s). All flows were adjusted to give the feed rates and contact times indicated in the Examples. The reactor effluent was sampled on line by a
20 Varian-6000 gas chromatograph using a 10 foot x 1/8" ID column containing Krytox® perfluorinated polyether on an inert support and a helium flow of 20-35 cc/minute. Gas chromatographic conditions were 70°C for 6.5 min. followed by temperature programming to 180°C at a rate
25 of 35°C/min. A flame ionization detector was used to provide relative areas.

EXAMPLE 1

This Example uses a Cr₂O₃ catalyst to disproportionate HCFC-124. The results at various
30 temperatures are shown in Table 1.

Catalyst: 5 g Cr₂O₃, no pretreatment

Feed: HCFC-124 (5 mL/min)

TABLE 1

<u>Temp</u>	<u>K(app)*</u>
start:	0.0
120°C	3.2×10^3
140°C	3.1×10^2
175°C	19
218°C	4.5
238°C	1.1
256°C	1.0
258°C	0.71
277°C	0.30
307°C	0.28

$$*K(app) = \frac{(\text{relative area HFC-125})(\text{relative area HCFC-123})}{(\text{relative area HCFC-124})^2}$$

- 5 It is evident from the results above that the formation of HFC-125 and HCFC-123 are favored at lower temperatures.

EXAMPLE 2

- 10 This Example demonstrates the conproportionation reaction whereby HCFC-124 is made from HCFC-123 and HFC-125. The results are shown in Table 2.

Catalyst: 10g Cr₂O₃ no pretreatment

Flows: HCFC-123 liquid @ 2 mL/hr and HFC-125 gas
~5 cc/min

TABLE 2

<u>Temp</u>	<u>F125</u> ^(l)	<u>F124a</u> ^(m)	<u>F124</u> ⁽ⁿ⁾	<u>F123a</u> ^(p)	<u>F123</u> ^(q)
277°C	71.5	0.29	41.4	1.9	266

- (l) F125 = CF₃CHF₂ (HFC-125)
 (m) F124a = CHF₂CClF₂ (HCFC-124a)
 5 (n) F124 = CF₃CHClF (HCFC-124)
 (p) F123a = CHF₂CCl₂F (HCFC-123a)
 (q) F123 = CF₃CHCl₂ (HCFC-123)

It is evident that HCFC-123 and HFC-125 were
 10 substantially interconverted to HFC-124.

EXAMPLE 3

This Example demonstrates disproportionation at
 various temperatures using supported Cr₂O₃ catalyst.

The results are shown in Table 3.

- 15 Catalyst: 4g 7.5% Cr₂O₃/Al₂O₃
 Activation: 15 min @ 300°C with CCl₄ at 2 mL/h
 Feed: HCFC-124 (with 0.4% HCFC-124a) at 10 mL/min

TABLE 3

<u>Temp</u>	<u>F125</u>	<u>F124a</u>	<u>F124</u>	<u>F123</u>
50°C	0.13	0.03	45	5
76°C	1.10	0.03	39	11
160°C	5.8	---	12	32

20

EXAMPLE 4

This Example demonstrates disproportionation at
 various temperatures using supported Cr₂O₃ catalyst.

The results are shown in Table 4.

- 25 Catalyst: 7.3g 19% Cr₂O₃/Al₂O₃
 Activation: 300°C with CFC-12 @ 25 mL/min for 30
 min
 Feed: HCFC-124, 5 mL/min

TABLE 4

Temp	F124a	F124	F125	F123a	F123
187°C	0.18	28	4.3	0.07	8.3
191°C	0.21	34	2.1	<.01	5.4
294°C	0.30	27	3.8	0.03	8.1
346°C	0.36	22	1.5	0.05	7.5

It is evident from Examples 3 and 4 that the interconversion of HCFC-124 to HFC-125 and HCFC-123 proceeds in the presence of supported Cr₂O₃.

EXAMPLE 5

This Example demonstrates the conproportionation reaction whereby HCFC-124 can be made from HCFC-123 and a mixture of materials containing HFC-125. The results are shown in Table 5.

Catalyst: 10g Cr₂O₃ (Pretreat: 30 min 385°C 6 mL/h CCl₄)

Flows: Liquid, 1 mL/hr; gas, 15 cc/min

TABLE 5

Temp	F116 ^(q)	F125	F115 ^(r)	F124	F114a ^(s)	F123
start gas	3.4	11.5	78	none	7.3	none
start liquid						100
297°C	2.8	17.4	140	5.0	1.1	8.7
355°C	2.4	12.8	120	5.6	0.9	11.4
400°C	2.2	11.4	120	5.1	1.0	9.7
450°C	2.3	12.5	120	4.5	3.9	8.2

(q) F116 = CF₃CF₃ (FC-116)

(r) F115 = CF₃CClF₂ (CFC-115)

(s) F114a = CF₃CCl₂F (CFC-114a)

It is evident that the interconversions of this invention can be achieved in the presence of various other halogen substituted hydrocarbons.

EXAMPLE 6

5 This Example demonstrates the effect of temperature on the equilibrium. Low temperature favors disproportionation. High temperature favors conproportionation. The results at various temperatures is shown in Table 6.

Catalyst: 30g Cr₂O₃

10 Activation: 350-375°C with CFC-12 @ ~20/min.

Feed: F124 ~5 mL/min

TABLE 6

Temp	F125	F115	F124a	F124	F133a	F114a	F123	K(app)
200°C	88	7	0.3	33	24	4.5	128	10.0
249°C	52	36	0.4	19.6	64	4.3	56	7.6
298°C	18	48	0.4	9.6	30	3.9	24	4.7
347°C	13	41	0.9	7.5	12.5	5.5	15.4	3.6
400°C	9	32	0.8	4.8	3.4	3.9	8.3	3.2

15 It is evident that at the relatively large catalyst dosage of this example, various other by-products can be produced in addition to the interconversion products of this invention, especially at high temperatures.

EXAMPLE 7

20 $\text{CF}_3\text{CHClF} \rightarrow \text{CF}_3\text{CHCl}_2 + \text{CF}_3\text{CHF}_2$

A 0.5" ID x 12" long Inconel® nickel alloy pipe was charged with 23.1 g (30 mL) of 29% CrCl₃/carbon. The bath was gradually heated to 400°C while nitrogen gas at a flow rate of 50 mL/min was passed through the reactor to remove traces of water. The temperature was then decreased to 350°C and nitrogen/HCFE-124 (6/1 molar ratio) was passed over the catalyst at a contact time of 30 s. The reactor effluent was analyzed with a Hewlett Packard HP 5890 gas chromatograph using a 20 foot long,

1/8" diameter, column containing Krytox® perfluorinated polyether on an inert support and a helium flow of 35 cc/min. Gas chromatographic conditions were 70°C for 3 minutes followed by temperature programming to 180°C at a rate of 6°C/min. The results of the reaction are shown in Table 7.

TABLE 7

<u>F125</u>	<u>F124</u>	<u>F114a (t)</u>	<u>F123</u>	<u>PCE (u)</u>	<u>Others</u>
32.4%	19.6%	4.7%	34.5%	3.2%	5.6%

- (t) F114a = $\text{CF}_3\text{CCl}_2\text{F}$ (CFC-114a)
(u) PCE = $\text{CCl}_2=\text{CCl}_2$

It is evident that interconversion of HCFC-124 to HFC-125 and HCFC-123 proceeds in the presence of supported CrCl_3 catalyst.

EXAMPLE 8HCFC-124 Disproportionation

A 0.5" ID x 12" long Inconel® nickel alloy pipe was charged with 2% $\text{CoCl}_2/\text{Al}_2\text{O}_3$ (20.4 g, 30 mL). The bath was gradually heated to 176°C while nitrogen gas at a flow rate of 50 cc/min was passed through the reactor to remove traces of water. The H_2/HF flow was continued at a bath temperature of 176°C for four hours. The HF flow was then stopped and only N_2 was passed over the catalyst overnight at a 176°C. The HF flow was started again the next day. After 10 minutes the HF flow was increased to 75 cc/min and the N_2 flow decreased to 25 cc/min. The bath temperature was then increased to 263°C at the higher HF flow rate and maintained under those conditions for 1.3 hours followed by the following heating profile: 281°C/13 min; 313°C/22 min; 352°C/15 min; and finally at 399°C for 15 min. The HF flow was then stopped and the temperature of the bath reduced to

reaction temperature. The results of passing HCFC-124 over the activated catalyst at a contact time of 60 seconds except for the experiment at 350°C for which the contact time was 30 seconds is shown in the table. The reactor effluent was analyzed with a Hewlett Packard HP 5890 gas chromatograph using a 20 foot long, 1/8" diameter, column containing Krytox® perfluorinated polyether on an inert support and a helium flow of 35 cc/min. Gas chromatographic conditions were 70°C for 3 minutes followed by temperature programming to 180°C at a rate of 6°C/min. The results of the reaction are shown in Table 8.

TABLE 8

Temp.	N ₂ /F-124	%F125	%F124	%F123	%Others
start	1/1	0.2	99	0.1	0.2
125°C	0/1	2	96	2	0.7
150°C	0/1	4	91	4	0.4
250°C	0/1	24	51	24	0.6
350°C	1/1	38	30	22	10*

*Included in others for this run was 0.6% CF₃CClF₂, 3% CCl₂=CClF, 1.6% CClF₂CCl₃ and 3.6% CCl₂=CCl₂.

It is evident that interconversion of HCFC-124 to HFC-125 and HCFC-123 proceeds in the presence of supported CoCl₂ catalyst.

Particular embodiments of the invention are included in the Examples. Other embodiments of the invention will become apparent to those skilled in the art from a consideration of the specification or practice of the invention disclosed herein. It is

understood that modifications and variations may be practiced without departing from the spirit and scope of the novel concepts of this invention. It is further understood that the invention is not confined to the particular formulations and examples herein illustrated, but it embraces such modified forms thereof as come within the scope of the claims.

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CLAIMS

What is claimed is:

- 5 1. A method for increasing in a composition the mole fraction of a selected compound of the formula $\text{CF}_3\text{CHF}_x\text{Cl}_{2-x}$ where x is an integer from 0 to 2 relative to the total mole fraction of the other two compounds having said formula comprising the steps of:
- 10 (a) providing a gaseous composition comprising at least one compound of said formula provided that (i) if the selected compound is either CF_3CHCl_2 or CF_3CHF_2 , said gaseous composition comprises CF_3CHFCl and the mole fraction of the selected compound
- 15 relative to the other two compounds in said gaseous composition is less than its equilibrium amount at 50°C , and (ii) if the selected compound is CF_3CHFCl , said gaseous composition comprises both CF_3CHCl_2 and CF_3CHF_2 and the mole fraction of the selected compound relative
- 20 to the other two compounds in said gaseous composition is less than its equilibrium amount at 500°C ;
- (b) contacting said gaseous composition with a catalyst selected from the group of catalysts consisting of catalysts comprising chromium as an oxide,
- 25 as a halide or as a halided oxide, in a valence state of three to six, and supported catalysts containing at least one metal selected from cobalt, copper, iron, manganese, nickel and zinc, for a time sufficient to provide substantial interconversion among the three
- 30 compounds having said formula; and
- (c) providing during said catalyst contact a temperature within the range of about 50°C to 500°C at which the mole fraction of the selected compound relative to the other two compounds increases.

2. The method of Claim 1 wherein the catalyst is Cr_2O_3 .
3. The method of Claim 1 wherein the catalyst is Cr_2O_3 supported on alumina.
4. The method of Claim 1 wherein the catalyst is Cr_2O_3 pretreated with CCl_4 .
5. The method of Claim 1 wherein the catalyst is CrCl_3 supported on carbon.
6. The method of Claim 1 wherein the catalyst is CoCl_2 supported on Al_2O_3 .
7. The method of Claim 1 where the selected compound is CF_3CFHCl and the gaseous composition of step (a) is derived from a feed of CF_3CHCl_2 and CF_3CHF_2 .
8. The method of Claim 1 where the selected compound is CF_3CHCl_2 and the gaseous composition of step (a) is derived from a feed of CF_3CFHCl .
9. The method of Claim 1 where the selected compound is CF_3CHF_2 and the gaseous composition of step (a) is derived from a feed of CF_3CFHCl .
10. The method of Claim 1 wherein the interconversion using said catalyst is conducted at about 200°C to 400°C .
11. In a process for preparing halogen substituted ethanes containing fluorine, a method for increasing the yield of a selected compound of the formula $\text{CF}_3\text{CHF}_x\text{Cl}_{2-x}$ where x is an integer from 0 to 2 relative to the total

yield of the other two compounds having said formula comprising the steps of:

(a) providing a gaseous composition comprising at least one compound of said formula provided that (i) if the selected compound is either CF_3CHCl_2 or CF_3CHF_2 , said gaseous composition comprises CF_3CHFCl and the mole fraction of the selected compound relative to the other two compounds in said gaseous composition is less than its equilibrium amount at 50°C , and (ii) if the selected compound is CF_3CHFCl , said gaseous composition comprises both CF_3CHCl_2 and CF_3CHF_2 and the mole fraction of the selected compound relative to the other two compounds in said gaseous composition is less than its equilibrium amount at 500°C ;

(b) contacting said gaseous composition with a catalyst selected from the group of catalysts consisting of catalysts comprising chromium as an oxide, as a halide or as a halided oxide, in a valence state of three to six, and supported catalysts containing at least one metal selected from cobalt, copper, iron, manganese, nickel and zinc for a time sufficient to provide substantial interconversion among the three compounds having said formula;

(c) providing during said catalyst contact a temperature within the range of about 50°C to 500°C at which the mole fraction of the selected compound relative to the other two compounds increases;

(d) separating at least a portion of the selected compound from the interconverted composition of step (c); and

(e) contacting at least a portion of the compounds remaining after said separation with a catalyst selected from said group of catalysts at a temperature within the range of about 50°C to 500°C for a time sufficient to produce an additional quantity of

said selected compound by providing substantial interconversion.

12. The method of Claim 11 wherein the catalyst of
5 step (b) is Cr_2O_3 .

13. The method of Claim 11 wherein the catalyst of
step (b) is Cr_2O_3 supported on alumina.

10 14. The method of Claim 11 wherein the catalyst of
step (b) is Cr_2O_3 pretreated with CCl_4 .

15 15. The method of Claim 11 wherein the catalyst of
step (b) is CrCl_3 supported on carbon.

16. The method of Claim 11 wherein the catalyst of
step (b) is CoCl_2 supported on Al_2O_3 .

17. The method of Claim 11 where the selected
20 compound is CF_3CFHCl and the gaseous composition of step
(a) is derived from a feed of CF_3CHCl_2 and CF_3CHF_2 .

18. The method of Claim 11 where the selected
compound is CF_3CHCl_2 and the gaseous composition of step
25 (a) is derived from a feed of CF_3CFHCl .

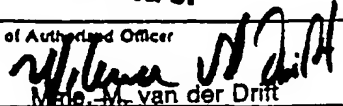
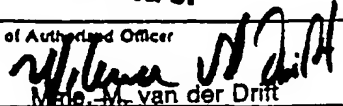
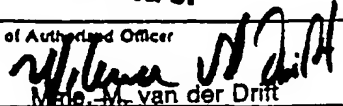
19. The method of Claim 11 where the selected
compound is CF_3CHF_2 and the gaseous composition of step
(a) is derived from a feed of CF_3CFHCl .

30 20. The method of Claim 11 wherein the
interconversion using said catalyst of step (b) is
conducted at about 200°C to 400°C .

INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 91/04135

I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all) ⁴ According to International Patent Classification (IPC) or to both National Classification and IPC IPC ⁵ : C 07 C 17/24, C 07 C 19/08																	
II. FIELDS SEARCHED <div style="text-align: center; border-top: 1px solid black; border-bottom: 1px solid black; margin: 5px 0;">Minimum Documentation Searched ⁷</div> <div style="display: flex; justify-content: space-between;"> <div style="width: 30%;">Classification System </div> <div style="width: 70%;">Classification Symbols</div> </div> <div style="display: flex; justify-content: space-between; margin-top: 10px;"> <div style="width: 30%;">IPC⁵</div> <div style="width: 70%;">C 07 C 17/00, C 07 C 19/00</div> </div> <div style="text-align: center; border-top: 1px solid black; border-bottom: 1px solid black; margin-top: 10px;">Documentation Searched other than Minimum Documentation to the extent that such Documents are included in the Fields Searched ⁴</div>																	
III. DOCUMENTS CONSIDERED TO BE RELEVANT⁸ <table border="1" style="width: 100%; border-collapse: collapse; margin-top: 5px;"> <thead> <tr> <th style="width: 10%;">Category ⁹</th> <th style="width: 60%;">Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²</th> <th style="width: 30%;">Relevant to Claim No. ¹³</th> </tr> </thead> <tbody> <tr> <td style="text-align: center; vertical-align: top;">A</td> <td>US, A, 4 145 368 (SWEENEY et al.) 20 March 1979 (20.03.79), see examples 1,2,6 (cited in the application).</td> <td style="text-align: center; vertical-align: top;">1, 2, 8, 10</td> </tr> <tr> <td style="text-align: center; vertical-align: top;">A</td> <td>EP, A1, 0 365 296 (IMPERIAL CHEMICAL INDUSTRIES) 25 April 1990 (25.04.90), see tables 1,2; claims.</td> <td style="text-align: center; vertical-align: top;">1, 2, 9</td> </tr> <tr> <td style="text-align: center; vertical-align: top;">A</td> <td>Chemical Abstracts, Volume 113, no. 3, issued 1990, July 16, (Columbus, Ohio, U.S.A.), Morikawa et al. "Isomerization of Freon 124a into Freon 124" see page 584, the abstract no. 23097c, JP-A-2-40 332 (Asahi Glass).</td> <td style="text-align: center; vertical-align: top;">1, 7</td> </tr> <tr> <td style="text-align: center; vertical-align: top;">A</td> <td>US, A, 4 766 260 (MANZER et al.)</td> <td style="text-align: center; vertical-align: top;">1, 7, 8, 10</td> </tr> </tbody> </table>			Category ⁹	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³	A	US, A, 4 145 368 (SWEENEY et al.) 20 March 1979 (20.03.79), see examples 1,2,6 (cited in the application).	1, 2, 8, 10	A	EP, A1, 0 365 296 (IMPERIAL CHEMICAL INDUSTRIES) 25 April 1990 (25.04.90), see tables 1,2; claims.	1, 2, 9	A	Chemical Abstracts, Volume 113, no. 3, issued 1990, July 16, (Columbus, Ohio, U.S.A.), Morikawa et al. "Isomerization of Freon 124a into Freon 124" see page 584, the abstract no. 23097c, JP-A-2-40 332 (Asahi Glass).	1, 7	A	US, A, 4 766 260 (MANZER et al.)	1, 7, 8, 10
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A	US, A, 4 766 260 (MANZER et al.)	1, 7, 8, 10															
<div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> <p>[*] Special categories of cited documents: ¹⁴</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> </div> <div style="width: 50%;"> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art</p> <p>"4" document member of the same patent family</p> </div> </div>																	
IV. CERTIFICATION <table border="1" style="width: 100%; border-collapse: collapse; margin-top: 5px;"> <tr> <td style="width: 50%; padding: 5px;"> Date of the Actual Completion of the International Search <div style="text-align: center;">03 September 1991</div> </td> <td style="width: 50%; padding: 5px;"> Date of Mailing of this International Search Report <div style="text-align: center;">24.09.91</div> </td> </tr> <tr> <td style="width: 50%; padding: 5px;"> International Searching Authority <div style="text-align: center;">EUROPEAN PATENT OFFICE</div> </td> <td style="width: 50%; padding: 5px;"> Signature of Authorized Officer <div style="text-align: center;">  M. van der Drift </div> </td> </tr> </table>			Date of the Actual Completion of the International Search <div style="text-align: center;">03 September 1991</div>	Date of Mailing of this International Search Report <div style="text-align: center;">24.09.91</div>	International Searching Authority <div style="text-align: center;">EUROPEAN PATENT OFFICE</div>	Signature of Authorized Officer <div style="text-align: center;">  M. van der Drift </div>											
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III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category *	Citation of Document, " with indication, where appropriate, of the relevant passages	Relevant to Claim No.
A	23 August 1988 (23.08.88), see claims 1,8; column 3, lines 62-69 (cited in the application). --	1,3,10
	US, A, 3 787 331 (GROPPELLI et al.) 22 January 1974 (22.01.74), see examples 5,6 (cited in the application). ----	

ANHANG
zum internationalen Recherchen-
bericht über die internationale
Patentanmeldung Nr.

ANNEX
to the International Search
Report to the International Patent
Application No.

ANNEXE
au rapport de recherche inter-
national relatif à la demande de brevet
international n°

PCT/US 91/04133 SAE 48460

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nannten internationalen Recherchenbericht
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Diese Angaben dienen nur zur Unter-
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This Annex lists the patent family
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In Recherchenbericht angeführtes Patentdokument Patent document cited in search report Document de brevet cité dans le rapport de recherche	Datum der Veröffentlichung Publication date Date de publication	Mitglied(er) der Patentfamilie Patent family member(s) Membre(s) de la famille de brevets	Datum der Veröffentlichung Publication date Date de publication
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